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First Ever Documented Total Calcaneus Replacement with 3D Printed Metallic Implant for Chronic Osteomyelitis after a Calcaneal Fracture in a Young, Healthy Individual—A Literature Review and Preliminary Case Report

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Abstract

Osteomyelitis of the calcaneus can be a limb threatening diagnosis, which is typically treated with antibiotic therapy with or without partial resection of the bone. Extensive infection of the bone commonly results in limb amputation via transtibial or transfemoral amputation, which can increase morbidity and mortality. This case report involves a 29-year-old male who sustained bilateral calcaneal fracture after a fall, who developed osteomyelitis of the right calcaneus after being treated with internal/external fixation and antibiotic therapy. In order to preserve the limb total calcaneal replacement with 3D printed implant was done.

Keywords

Osteomyelitis, Calcaneal Replacement, 3D Implant, Calcaneal Fracture, Below Knee Amputation

1. Introduction

Osteomyelitis of the calcaneus is a devastating diagnosis. Approximately 3% - 10% of bone infections involve the calcaneus [1]. Osteomyelitis of the calcaneus typically results from a surgical site infection, post-traumatically, or secondary to a chronic ulceration of the heel [1]. Calcaneal osteomyelitis can occur at any age and typically affects patients with multiple comorbidities such as diabetes and

neuropathy [1].

No standard treatment protocol exists in the literature but a multidisciplinary team approach is most often utilized. Treatment typically involves therapy with long-term intravenous antibiotics with or without partial resection of the infected calcaneus. If an ulceration exists, wound management with local wound care or surgical debridement with the use of grafting in conjunction with negative pressure wound vac therapy is often required. Total calcaneal resection is reserved for definitive infection control as well as for avoidance of transtibial and transfemoral amputations. However, as total calcaneal resection leads to complete loss of function of the limb, it is typically reserved as a last resort before definitive lower extremity amputation. It has been shown that avoidance of transtibial and transfemoral amputations may actually decrease both morbidity and mortality [2].

Despite appropriate antibiotic and surgical treatment, the long-term recurrence rate of osteomyelitis remains approximately 20% - 30% [3]. In individuals with chronic osteomyelitis of the calcaneus without heel ulcerations or major comorbidities, a lower extremity amputation can feel like an impractical approach for a limb that is still functional. Prolonged antibiotic suppression therapy is often utilized in patients who are unwilling or unable to undergo surgical intervention. Unfortunately, the optimal duration of antibiotic suppression remains unknown [3].

Total calcaneal replacement with an implant has been reported in the literature for treatment of invasive bone tumors. Only three case reports exist today [4] [5] [6]. Total calcaneal replacement with an implant for chronic osteomyelitis has never been reported in the literature. In this report, we present the first ever documented total calcaneus replacement with 3D printed metallic implant for chronic osteomyelitis of the calcaneus in a 29-year-old man.

2. Case Report

A 29-year-old male with past medical history significant only for tobacco use sustained bilateral calcaneal fractures after slipping and falling 16 feet from a metal roof while at work. The patient was admitted to an outside smaller community hospital and underwent a primary subtalar joint fusion of the right foot, the timing of the encounter is unknown at this time. He was scheduled to have surgery to his left foot several days later but postoperatively became tachycardic and febrile and was transferred to a Level 1 trauma center for possible sepsis. He was started on Vancomycin and Zosyn, the length of time of antibiotics is unknown, due to inability to access hospital records. At the hospital he underwent an application of an external fixator of the left foot. No infectious causes for his symptoms were discovered and he was eventually discharged home. His postoperative period was quite uneventful until one month later he would be found to have redness and swelling with surgical site dehiscence of his right foot. He was admitted to the hospital and underwent an incision and drainage with wound vac application. Hardware was left in place at that time. Intraoperative

bone cultures grew Methicillin Resistant Staphylococcus Epidermidis and Finegoldia Magna. The patient was treated with 6 weeks of IV vancomycin per Infectious Disease recommendations for treatment of osteomyelitis. He reportedly missed several doses of vancomycin due to issues with care coordination as this was a Worker's Compensation injury. There was some difficulty maintaining appropriate tough levels, and was switched to oritavancin for the duration of his antibiotic therapy.

He was doing well until at approximately 5 months from his index procedure he presented to the Emergency Department at an outside facility due to concerns for a right foot infection. A bone scan was obtained which was concerning for osteomyelitis of the right calcaneus. He subsequently underwent irrigation and debridement with hardware removal of the right foot during this admission. Intraoperative wound cultures grew MRSA. However, cultures obtained from the hardware and bone grew MSSA. The patient was eventually discharged on 8 weeks of IV daptomycin.

The patient was referred to our institution for evaluation after being informed he would likely require suppressive antibiotic therapy for life unless he elected to undergo a below knee amputation for definitive treatment of his osteomyelitis. On clinical exam, the patient was found to have a small wound to his right foot in the area of his prior lateral surgical site (**Figure 1**). Radiographs obtained revealed nonunion of a comminuted calcaneus fracture as well as nonunion of prior subtalar joint fusion. A radiopaque area to the central aspect of the calcaneus was observed consistent with bone cement from prior procedure (**Figure 2**). Conservative vs surgical treatment options were discussed with the patient. It was explained to the patient that a below-knee amputation was a very viable option for him. However, the patient was not agreeable to this. A total calcanectomy with implantation of 3D printed implant was also discussed with the patient

Figure 1. Small wound to the right foot lateral surgical incision.

Figure 2. Radiographs showing bone cement place from previous surgery.

which he was agreeable to. The patient underwent CT scans of both his right and left lower extremities for preoperative planning as well as for implant construction (**Figure 3**).

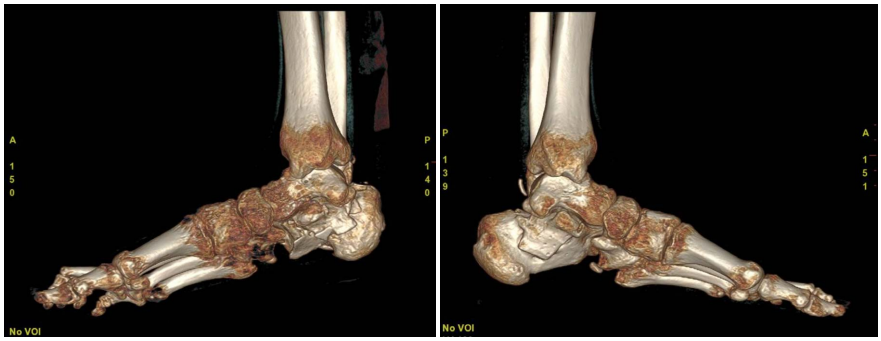
The implant was designed based on features utilized in three prior total calcaneal implant case reports in the literature [4] [5] [6]. Prior to surgical intervention on the patient, the surgical procedure was performed on a side-matched cadaver limb. A trial plastic calcaneal 3D printed implant was utilized.

The patient underwent total calcanectomy with implantation of 3D Printed Metallic Implant. The open wound to the lateral aspect of his foot was excised as well. A hemovac drain was inserted and the patient was placed in a well-padded posterior splint. He was admitted to the hospital for postoperative observation. The patient was started on IV vancomycin on admission. The hemovac drain was pulled one day postoperatively and he was placed in a short leg cast. He was discharged home on Keflex per his Infectious Disease doctor's recommendations. Intraoperative bone culture grew MSSA and his bone biopsy was positive for chronic osteomyelitis. Postoperatively he remained non weight bearing in a below knee cast. He underwent weekly cast changes. His sutures were removed at two weeks postoperatively. He was transitioned out of the cast at 6.5 weeks and began partial weight bearing in a camboot with referral to physical therapy at that time. He gradually progressed to full weight bearing in a camboot with single crutch use. At week 14 he was fully weight bearing in normal shoes with an AFO.

Patient was to be on 1 year of antibiotics following surgery due to the patient's prior complicated history and suppression therapy. Plan was provided by his outside infectious disease provider he was already established with.

Surgical Technique:

The patient was placed in a prone position. Attention was directed to the posterior aspect of the heel where an incision was made beginning at the myotendinous junction of the Achilles tendon. The incision extended distally in a curvilinear fashion past the calcaneocuboid articulation to the level of the plantar midfoot (**Figure 4**). The incision was deepened down through the level of the subcutaneous tissue taking care to maintain a full-thickness flap. Meticulous anatomical dissection was carried down to the level of the calcaneus. The Achilles



(a) (b)

Figure 3. (a, right foot) Preop CT scans of right foot; (b, left foot) Preop CT scans of left foot, referenced to make the 3D implant.

Figure 4. Curvilinear incision of the posterior ankle extending to the plantar foot.

tendon was detached from the calcaneus as distally as possible and tagged. Next, the plantar fascia, flexor digitorum brevis and quadratus plantae were resected from their insertions and tagged together. Once the plantar structures were completely freed, attention was directed to the medial aspect of the calcaneus. Meticulous dissection was performed in order to leave the neurovascular bundle intact. The deltoid ligament was identified and tagged prior to detachment. The calcaneonavicular ligament was identified, tagged, and then detached from the calcaneus. Attention was then directed to the lateral aspect of the calcaneus. The lateral collateral ligaments were identified, tagged, and detached (**Figure 5**). Attention was then directed to the calcaneocuboid joint. Dissection was carried down through the joint capsule opening the joint. Next, dissection was carried out along the lateral aspect of the subtalar joint through the joint capsule. The joint was carefully dissected from a lateral approach. There was noted to be a

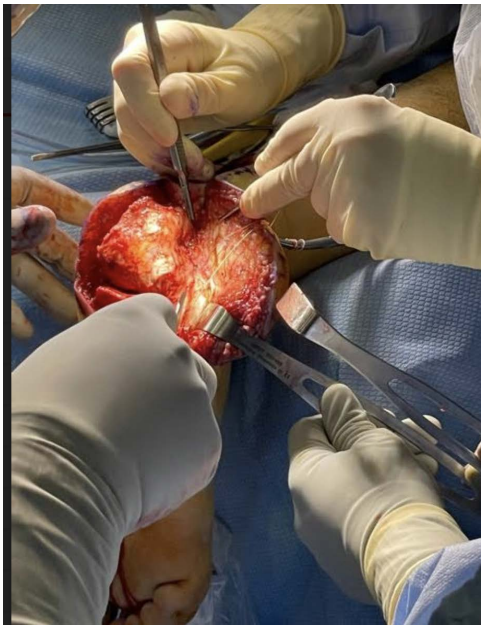


Figure 5. Suture tagging of lateral collateral ligaments.

partial fusion of the subtalar joint (posterior-medially) from the previous procedure. An osteotome was placed within the joint and utilized to carefully separate the partial fusion. Once this was completed the calcaneus was easily removed from the foot in total (**Figure 6**). The calcaneus was placed on the back table (**Figure 7**). The calcaneus was inspected. Portions of the bone were noted to be significantly unhealthy. Some residual cement was noted to the central aspect of the calcaneus. A sinus tract was noted to the lateral aspect of the calcaneus as well. Several pieces of bone were sent to pathology as well as microbiology for culture and sensitivity. A deep tissue culture swab was obtained in the area of the sinus tract. The talus was inspected. No cartilage was noted in the area of prior fusion and the remaining cartilage was removed from the talus with curettes and osteotomes and the bone was remodeled to fit the calcaneal implant. Next, the trial calcaneus was placed into position and the soft tissue was pulled around it to make sure the soft tissue envelope would accommodate this. It was noted to be an excellent fit. The actual 3D printed calcaneal implant was then packed with bone graft in all of the porous areas in order to stimulate bone growth within the implant. Prior to implantation, fiberwire was threaded through the implant in various locations utilizing a flexible needle passer for reattachment of all the pre-tagged ligamentous and tendinous structures. The fiberwire from the implant was then passed through the Deltoid and Spring ligaments. Once the implant was then positioned against the talus utilizing fluoroscopic guidance and a k wire was placed through the implant into the talus for temporary fixation. The Deltoid and Spring ligaments were tied down to the implant. The implant was then secured utilizing a 7.0 partially threaded cannulated screw through the implant itself into the talus. Intraoperative fluoroscopy was again utilized to confirm position and fixation which was all noted to be excellent.

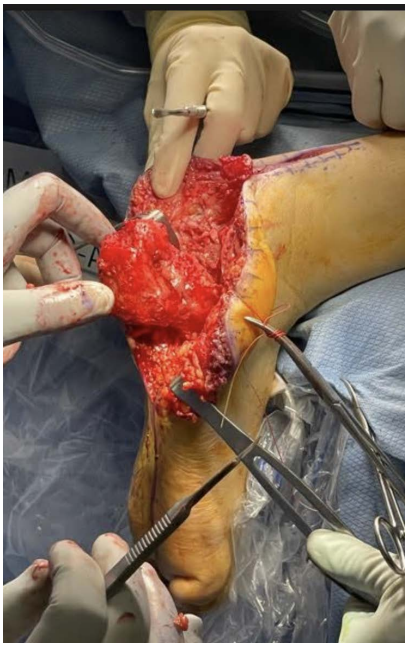


Figure 6. Removal of the right calcaneus.

Figure 7. Inspection of the calcaneus.

Krakow technique was performed on both sides of the Achilles tendon. The Achilles was carefully re-attached to the implant in a porous area designed on the posterior-superior aspect of the implant. The quadratus plantae and the plantar fascia was reattached to the porous portion on the plantar surface of the implant followed by the lateral collateral ligaments. The surgical site was flushed with copious amounts of sterile saline. A hemovac drain was placed to the posterior/posterior-plantar aspect of the right heel and exited on the lateral aspect of the leg. The deep soft tissue coapted utilizing 2-0 vicryl. The subcutaneous tissue was coapted utilizing 3-0 monocryl and the skin was coapted utilizing 2-0 prolene. Next, attention was directed to the invaginated skin on the lateral aspect of

the right foot which was excised with an elliptical incision. The patient was placed in a well-padded plantarflexed splints.

3. Discussion

An extensive literature search using the MEDLINE and Google Scholar databases resulted in 14 case reports/case series involving 28 patients requiring total calcaneal replacements with either autograft, allograft, or custom implants for various pathologies. 26 of the 28 patients underwent calcaneal replacement due to bone tumors. One patient underwent replacement after a crush injury and one patient underwent replacement due to osteomyelitis.

Of the 26 patients with bone tumors, three patients with tumors of differing histopathology underwent total calcaneal replacements with custom implants [4] [5] [6]. Chou *et al* was the first to perform a total calcaneal replacement with a 3D printed implant [4]. The authors' reasoning for attempting replacement with a custom implant was due to concerns for decreased mechanical integrity, fracture risk, infection, as well as nonunion with an allograft or autograft. Most impressively, they followed this patient for a total of 12 years with excellent results.

The two other case reports involving 3D printed implants did not reveal any novel findings other than being able to improve the implant characteristic. For example, Imanishi and Choong utilized a Cincinnati approach to resect the calcaneus and utilized a titanium implant that weighed 280 g [5]. Park *et al* utilized a similar approach to resect the calcaneus and incorporated a titanium implant that weighed only 104 g [6].

In this report, we present the first ever documented total calcaneus replacement with 3D printed metallic implant for chronic osteomyelitis of the calcaneus. As previously mentioned, there is only one documented total calcanectomy with allograft replacement for osteomyelitis in the literature. Brenner *et al* described a 28 year old male who sustained a comminuted calcaneal fracture after a fall from a height of 2.5 meters. He underwent open reduction internal fixation of the calcaneus initially but developed an infection with exposed hardware. He subsequently underwent removal of hardware with partial calcanectomy. He underwent several other procedures with eventual removal of the remainder of his calcaneus with allograft. In regards to our present case, we did not feel allograft was a viable option for the patient. There are several reasons to not use allograft, especially in an area of weightbearing including high incidence of fractures, mechanical compromise of the graft, infection, and nonunion [4]. What made this case even more challenging is that the 3D implant was designed based on a fractured calcaneus, since the patient's injury involved bilateral calcaneal fractures.

As mentioned earlier osteomyelitis of the calcaneus is a diagnosis primarily seen in patients with diabetes and neuropathy. Performing the procedure on these types of patients would not be recommended and should be treated with partial calcanectomy or below knee amputation. It is not typically seen after surgical treatments of calcaneal fractures. Although calcaneal implants have been

done to treat bone tumors, the research available is limiting. It is recommended to discuss with a surgeon who has experience with procedure and use cadaveric specimens to prepare and practice the procedure prior to the operation day. It is important to note that treatment with 3D implants involves careful patient selection. In the case of total calcaneal replacement it should be noted that subtalar fusion is recommended, as well as careful dissection and reattachment of the vital soft tissue structures, in order to maintain stability of the hindfoot and provide a functional limb.

4. Conclusion

Osteomyelitis of the calcaneus is typically seen in patients with multiple comorbidities, such as diabetes and neuropathy. No standard treatment protocol exists, but the majority of patients are treated with antibiotic therapy with or without partial calcanectomy. The patients who fail antibiotic therapy or those with extensive infection of the calcaneus will often require transtibial or transfemoral amputations. Our case report involves a 29-year-old male with a past medical history of tobacco use, who developed osteomyelitis after a calcaneal fracture, internal/external fixation and antibiotic therapy. Total calcaneal replacement has been done for patients with invasive bone tumors, but it should also be considered for other treatment options such as osteomyelitis. This option can help preserve the limb, decreasing both morbidity and mortality.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Merlet, A., Cazanave, C., Dauchy, F.-A., Dutronc, H., Casoli, V., Chauveaux, D., De Barbeyrac, B. and Dupon, M. (2014) Prognostic Factors of Calcaneal Osteomyelitis. *Scandinavian Journal of Infectious Diseases*, **46**, 555-560. https://doi.org/10.3109/00365548.2014.914241

[2] Walsh, T.P. and Yates, B.J. (2013) Calcanectomy: Avoiding Major Amputation in the Presence of Calcaneal Osteomyelitis—A Case Series. *The Foot*, **23**, 130-135. https://doi.org/10.1016/j.foot.2013.09.002

[3] Nowak, M.A., Winner, J.S. and Beilke, M.A. (2015) Prolonged Oral Antibiotic Suppression in Osteomyelitis and Associated Outcomes in a Veterans Population. *American Journal of Health-System Pharmacy*, **72**, S150-S155. https://doi.org/10.2146/sp150022

[4] Chou, L.B. and Malawer, M.M. (2007) Osteosarcoma of the Calcaneus Treated with Prosthetic Replacement with Twelve Years of Followup: A Case Report. *Foot & Ankle International*, **28**, 841-844. https://doi.org/10.3113/FAI.2006.0841

[5] Imanishi, J. and Choong, P.F.M. (2015) Three-Dimensional Printed Calcaneal prosthesis Following Total Calcanectomy. *International Journal of Surgery Case Reports*, **10**, 83-87. https://doi.org/10.1016/j.ijscr.2015.02.037

[6] Park, J.W., Kang, H.G., Lim, K.M., Kim, J.H. and Kim, H.S. (2018) Three-Dimen-

sionally Printed Personalized Implant Design and Reconstructive Surgery for a Bone Tumor of the Calcaneus. *JBJS Case Connector*, **8**, e25.
https://doi.org/10.2106/JBJS.CC.17.00212